Supplementary material for Pitakaso et al., "Modified Differential Evolution Algorithms for Multi-Vehicle Allocation and Route Optimization for Employee Transportation", *Engineering Optimization*, 2019.

Table S1. The average computational time that the alternative heuristics first found the optimal solution.

Approach	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	avg.
DE-B1	0.041	0.042	0.037	0.038	0.158	3.095	0.157	0.531	0.355	1.603	0.6457
DE-B2	0.021	0.020	0.022	0.023	0.030	0.122	0.016	0.126	0.134	0.149	0.1074
DE-B3	0.029	0.021	0.025	0.028	0.032	0.124	0.025	0.145	0.158	0.197	0.1131
DE-B4	0.037	0.032	0.029	0.043	0.059	0.524	0.136	0.318	0.567	0.408	0.1953
DE-B5	0.038	0.038	0.031	0.041	0.031	0.224	0.102	0.218	0.545	0.349	0.1287

Note: avg.= average computational time.

Table S2. P-value of the computational time comparison of the second and the first proposed heuristics to find the optimal solution.

Approach	DE-A2	DE-A3	DE-A4	DE-A5	DE-B1	DE-B2	DE-B3	DE-B4	DE-B5
DE-A1	0.00512*	0.0323*	0.0366*	0.00512*	0.00512*	0.00512*	0.00512*	0.00512*	0.00512*
DE-A2	-	0.00512*	0.03662*	0.00512*	0.00694*	0.01428*	0.02088*	0.00438*	0.00512*
DE-A3		-	0.00512*	0.00512*	0.00512*	0.02224*	0.0814	0.02852*	0.1100
DE-A4			-	0.3843	0.05876	0.03662*	0.00512*	0.0164*	0.00512*
DE-A5				-	0.2351	0.00512*	0.00512*	0.00512*	0.00512*
DE-B1					-	0.00512*	0.00512*	0.05875*	0.00512*
DE-B2						-	0.00512*	0.00338*	0.0038*
DE-B3							-	0.03236*	0.00512*
DE-B4								-	0.2627

Note: * significantly different.

Table S3. Results of the large size of test instances of the alternative and the proposed heuristics.

Approach	Term	Case 1	Case 2	Case 3	Case 4	Case 5
Lower bound generated by Lingo v.11 for Windows	Cost (Baht)	421,902	480,093	47,6921	477,895	615,798
	Computational time (sec.)	28,800	28,800	28,800	28,800	28,800
Current Practice	Cost (Baht)	512,371	527,884	528,891	563,153	690,435
	Computational time (sec.)	400	500	550	550	800
	No. of bus stops (stops)	94	128	133	166	166
	No. Buses (buses)	28	28	28	29	36
DE-A1	Cost (Baht)	460,985	500,585	505,489	505,221	650,981
	Computational time (sec.)	405.82	565.81	528.89	549.81	790.87
	No. of bus stops (stops)	40	61	65	87	89
	No. Buses (buses)	23	27	25	25	36
DE-A2	Cost (Baht)	425,871	484,979	484,589	482,456	622,817
	Computational time (sec.)	396.41	543.51	549.44	504.72	774.59
	No. of bus stops (stops)	43	57	58	67	84

	No. Buses (buses)	24	22	23	25	32
DE-A3	Cost (Baht)	439,824	489,991	499,981	485,539	634,651
	Computational time (sec.)	382.91	520.41	548.54	552.45	961.59
	No. of bus stops (stops)	45	67	60	69	95
	No. Buses (buses)	24	23	24	24	33
DE-A4	Cost (Baht)	448,883	493,911	484,585	491,899	633,801
	Computational time (sec.)	395.89	501.16	529.98	557.65	698.83
	No. of bus stops (stops)	53	52	60	83	86
	No. Buses (buses)	24	25	24	28	34
DE-A5	Cost (Baht)	459,533	499,795	492,856	494,871	638,927
	Computational time (sec.)	386.03	505.81	569.88	553.91	696.84
	No. of bus stops (stops)	51	56	53	74	86
	No. Buses (buses)	27	28	27	26	35
DE-B1	Cost (Baht)	455,724	491,548	492,568	500,994	647,381
	Computational time (sec.)	402.49	561.84	520.45	537.53	788.58
	No. of bus stops (stops)	36	57	61	82	86
	No. Buses (buses)	20	21	23	22	31
DE-B2	Cost (Baht)	423,509	481,221	482,199	480,192	620,411
	Computational time (sec.)	394.12	544.55	541.45	508.11	772.56
	No. of bus stops (stops)	41	56	55	64	83
	No. Buses (buses)	22	20	20	23	31
DE-B3	Cost (Baht)	438,259	489,491	489,581	484,395	632,575
	Computational time (sec.)	382.91	520.41	548.54	552.45	961.59
	No. of bus stops (stops)	44	64	58	69	90
	No. Buses (buses)	24	23	24	24	33
DE-B4	Cost (Baht)	447,562	491,949	484,134	490,720	632,214
	Computational time (sec.)	395.071	502.456	530.568	553.491	694.351
	No. of bus stops (stops)	52	52	59	81	86
	No. Buses (buses)	24	24	23	27	32
DE-B5	Cost (Baht)	459,512	498,996	484,458	493,678	630,145
	Computational time (sec.)	388.51	502.49	562.58	551.92	698.40
	No. of bus stops (stops)	49	54	53	71	84
	No. Buses (buses)	24	23	24	24	34

Table S4. Results of the case study.

I = 11,340, J = 472 and K= 300				
Method	**Computational time**	**Total Cost**	**No. of buses used**	**No. of bus stops used**
current practice	N/A	4,064,964	248	472
DE-A1	8,955.5	3,812,896	240	329
DE-A2	8,351.0	3,658,721	234	327
DE-A3	8,338.5	3,697,417	237	331
DE-A4	8,729.8	3,752,188	232	330
DE-A5	8,684.8	3,795,739	234	332
DE-B1	8,654.8	3,671,788	235	320
DE-B2	8,388.1	3,544,641	218	314
DE-B3	8,341.2	3,648,730	224	320
DE-B4	8,593.7	3,654,178	224	321
DE-B5	8,690.7	3,660,885	226	324

Procedure Proposed DE-B algorithm

Input: Groups of vectors - Employee ($N1$), Bus_Stop ($N2$), and Bus ($N3$), Recombination_Rate (CR), Scaling_Factor (F)

Output: Near optimal solution

```
procedure EmployeeTransportation(N1, N2, N3)
begin
    while Stopping Criteria do
Step1 to Step5 are Initial Population
Step1:
        Initialize groups of vectors: Group employee (N1 × 5), Group bus_stop (N2 × 4), Group bus (N3 × 4)
Step2:
        Select a bus from the order of buses in a single vector (I3)ofN3
Step3:
        Move the selected bus to the order of bus stops in a single vector (I2)ofN2
Step4:
        Move the order of employees in a single vector (I1)ofN1 to the selected bus stop
        while (the walking distance ≤ the predefined distance) and (the capacity is not exceeded) do
            Assign the awaiting employee to the selected bus
Step5:
            if The capacity of the selected bus is full then
                The full bus returns to the depot
                Go to Step2:
            else
                All unassigned employees are moved to the next bus stop in I2
                if the current worker has no other bus stops that have walking distance less than the predefined number then
                    The workers can be assigned to the bus stop that is currently used
                    The next order of the bus will be used to collect the workers and combine it with the workers from the next bus stops
                    Go to Step3:
                end
Step6: Mutation Process
                In Formula(1), randomly select 3 vectors out of I1, I2, I3 target vectors (X^{best-s}_{i,j,G})
                Use Formula(2) − (5) to select r1, r2, r3 vectors from a set of the best target vectors (X^{best-s}_{i,j,G})
                Generate a set of mutant vectors (V^s_{i,j,G}) from Formula(6)
Step7: Recombination Process
                Apply Formula(7) to get a set of trial vectors (U^s_{i,j,G})
Step8: Selection Process
                Use Formula(8) to get the best objective function between f^{best}(X^s_{i,j,G}) and f^{best}(U^s_{i,j,G})
                end
end
```

The proposed DE-B algorithms

Figure S1. Pseudo codes of the alternative DE algorithm.